ACADEMIC SCIENTISTS MOBILITY: THE HIDDEN PIPE OF TACIT KNOWLEDGE TRANSFER FROM ACADEMIA TO INDUSTRY

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1. Abstract

Knowledge transfer from academia to industry is critical to support economic growth and to contribute to a local open innovation ecosystem. Research on University-industry knowledge transfer (UIKT) focus on codified knowledge; mainly patents. However, the vast majority of knowledge produced by academia is tacit and, in some cases, cannot be made explicit and remains embodied in individuals. Therefore, tracking explicit knowledge transfer dramatically reduces the real understanding of UIKT. This article adopts another perspective to evaluate UIKT by tracking the interorganizational professional mobility of academic scientists in whom is embodied tacit knowledge. One argues that professional mobility of PhD graduates is an instrument to measure tacit knowledge transfer from academia to industry. Through a database of the PhD graduates of a large pluridisciplinary European university, the results show that analyzing PhD graduates' mobility gives a broader understanding of UIKT. Some scientific domains transfer more tacit knowledge to industry than others, and some industrial domains pull tacit knowledge from a more diverse set of scientific domains than others. Finally, the university provides highly qualified scientists to its local ecosystem depending on the citizenship of PhD graduates (supply) and local industry (demand).

Keywords: knowledge transfer, tacit knowledge, informal mechanisms, mobility, socialization

2. Introduction

Knowledge transfer from academia to industry is critical to nurture economic growth (Agrawal, 2001; Lilles & Rõigas, 2017). Universities explore new frontiers of knowledge that may lead to scientific discoveries that should be transferred to industry to be exploited in an industrial way. Therefore, this raises the critical question of University-Industry knowledge transfer (UIKT): to what extent universities transfer cutting edge scientific knowledge to industry? Ecosystem of innovation perspective raises a subsequent question: to what extent local universities transfer tacit knowledge to local industrial clusters? Such questions are critical for local and national policy makers that fund and support scientific research in universities.

Most of empirical research on UIKT use patent-based methods (patent licensing, co-patenting between universities and firms, publication citations in patents and patents of academic scientists moving to industry) to measure knowledge transfer (Hayter et al., 2020). Nevertheless, many researchers highlight the limits of patents to capture knowledge transfer (Agrawal & Henderson, 2002; Agrawal, 2001). Patents are explicit knowledge and encapsulate a limited part of knowledge produced by academia. Focusing on patent-based methods might underestimate UIKT. Tacit knowledge represents a large proportion of the knowledge created by universities (Hayter et al., 2020) and part of it is not made explicit through patents. This raises the question of tacit knowledge transfer from academia to industry, especially in academic fields that do not patent (e.g., social science or computer science). What are the pipes of tacit UIKT and how to measure such transfer of uncodified knowledge?

To illustrate the issue related to this question, we consider the example of Richard Thaler. He received a Nobel Prize in economics for his contribution to behavioral economics and is Professor of Finance at the University of Chicago. With Russell Fuller, former Professor of Finance at Washington State University and investment expert, they created, in 1993, *Fuller & Thaler Asset Management*, an asset management firm based on the behavioral finance theory[1]. The firm has recruited Raife Giovinazzo who did his PhD in Finance at the University of Chicago under the supervision of Richard Thaler. By creating a financial start-up, we may consider that Thaler, Fuller and Giovinazzo transferred knowledge from academia to the finance industry. By 2021, the firm is successful and manages $13,2 billion[2]. However, by usual standard there is no UIKT. Indeed, neither Thaler, Fuller or Giovinazzo for themselves or for the firm have patented anything at the US Patent Office. However, it is difficult to contest the reality of the UIKT. Scholars highlight that informal ties are an important medium of tacit knowledge transfer (Meyer-Krahmer & Schmoch, 1998; Cohen et al., 2002). We build on Simon (1991) and Nonaka (1994) that point out that tacit knowledge is embodied in individuals and that socialization is required to transfer tacit knowledge. Socialization is the "process of creating tacit knowledge through shared experience" (Nonaka, 1994, p. 19).

To contribute to the field of interorganizational knowledge transfer and, more specifically, to UIKT, one builds a conceptual framework based on Granovetter's theory of embeddedness (1973, 1985, 2005). One considers two kinds of socialization supporting tacit UIKT: weak socialization based on weak ties between individuals remaining in two different organizations (i.e. university and firm) and strong socialization based on strong ties built through professional mobility from one organization to another that brings people in the same organization (i.e. from university to firm). In this perspective, one proposes to empirically focus more specifically on UIKT related to academic scholars' professional mobility. Academic knowledge is primarily

[1] Fuller & Thaller Asset Management, Inc. (n.d.). *About | Fuller & Thaler Asset Management, Inc.* Fullerthaler.Com. Retrieved 13 March 2021, from https://www.fullerthaler.com/about

[2] Bloomberg

tacit knowledge and embodied in human heads. Academic scholars' mobility helps to track tacit knowledge transfer in a similar manner that patent licensing contributes to capture explicit knowledge transfer. Investigating knowledge transfer on the basis of mobility rather that on the basis of patents allow to shed a new light on academic knowledge transfer et renew the debate on the interest for public policy makers and organizations to finance academic research.

We build on previous research that consider professional mobility of academic scientists (i.e., PhD graduates and professors) from academia to industry (Bekkers & Bodas Freitas, 2008; Buenstorf & Heinisch, 2020; Mangematin & Robin, 2003). We follow the professional and geographical mobility of 377 PhD graduates of a large pluridisciplinary European university who defended their thesis in 2014 and 2015 and represent all academic fields. The article is structured as follow: The first part contains the literature review and conceptual framework on UIKT, the second part contains our conceptual model, the third part explains our methodology, the fourth shows our results. Finally, we discuss the result and underline the limits of the study.

3. Literature review and conceptual framework on UIKT

3.1 The nature of academic knowledge

A well-established epistemological distinction is made between two kind of knowledge: tacit and explicit (Polanyi, 1966). At the beginning all knowledge is tacit and resides in individuals (Nonaka, 1994; Simon, 1991). Some is made explicit through codification (Cowan et al., 2000): books, articles, documents, patents or databases. However, if all explicit knowledge is at some point tacit, all tacit knowledge may not be made explicit and remain tacit.

Explicit or tacit knowledge describe the nature of knowledge (Bozeman, 2000). Explicit knowledge is "knowledge that is transmittable in formal, systematic language" (Nonaka, 1994, p. 16). Tacit knowledge is knowledge that is not or cannot be made explicit, as it "has a persona quality, which makes it hard to formalize and communicate … [and] is deeply rooted in action, commitment, and involvement in a specific context" (Nonaka, 1994, p. 16). Examples of tacit knowledge are personal experiences, judgment, insights and skills (Chugh et al., 2015). These two constructs should not be conceptualized as a dichotomy, but more as extremes on a continuum (Inkpen & Dinur, 1998) due to the irreducible part of tacit knowledge in all types of knowledge (Polanyi, 1966).

Such differences apply to academic knowledge. Explicit academic knowledge is codified knowledge such as articles, theses, books or patents. Tacit academic knowledge is knowledge embodied in scientists and which cannot be fully articulated (Bramwell & Wolfe, 2008) such as failed trials and knowledge acquired through the research process (Bramwell & Wolfe, 2008; Buenstorf & Heinisch, 2020).

Academic articles, PhD theses, books or patents cannot codify all the knowledge embodied in academic scientists (Buenstorf & Heinisch, 2020). In most of knowledge, and also academic knowledge, tacit and explicit knowledge are imbricated and interact together. A patent or an academic article does not capture all knowledge of its inventor. Some of it remain tacit and embodied in the academic scientist. Tacit knowledge can never be totally made explicit, and thus cannot be merely transferred per se. Moreover, in some academic fields (such as, e.g., sociology, psychology, management or finance), knowledge is not patentable.

The nature of the knowledge influences the transfer mechanism that will convey this knowledge (Bekkers & Bodas Freitas, 2008). Schartinger et al. (2002) highlighted "the degree of codification, the tacitness or the embeddedness in technological artefacts" (p. 304) among factors that determine through which channel knowledge could be transferred. The elements above underline the irreducible tacit dimension of knowledge and raise the question of the interorganizational transfer of tacit knowledge.

3.2 Mechanisms of tacit knowledge transfer from academia to industry

Knowledge transfer mechanisms can be categorized into two categories: formal and informal mechanisms (Bozeman, 2000). Formal mechanisms are the privileged medium for explicit knowledge transfer when informal mechanisms are the one for tacit knowledge transfer. Formal mechanisms are "ones that embody or directly result in legal instrumentality such as … a patent, license or royalty agreement" (Link et al., 2007, p. 642). The usual process of UIKT assumes that an academic scientist patents an invention, often with the help of a technology transfer office, and such patent is licensed to a business to be transferred.

Most of the research on UIKT has focused on formal mechanisms and explicit knowledge (Grimpe & Hussinger, 2013). Patents are a widely used measure in knowledge transfer literature (see, e.g., Thursby & Thursby, 2002) as the data is easily accessible (Hayter et al., 2020). Literature often focalizes on specific faculties or industrial domains that patent inventions (see, e.g., Azagra-Caro et al., 2017 and Balconi & Laboranti, 2006 for microelectronics; Crespi et al., 2011 for physical sciences and engineering disciplines) and other faculties and industrial domains are often ignored, mainly those that do not patent.

Nevertheless, various studies showed that patenting is a minority activity within UIKT activities (Agrawal & Henderson, 2002; D'Este & Patel, 2007), and highlighted various issues with the use of patent-based methods to investigate UIKT (Crespi et al., 2011; Duguet & MacGarvie, 2005). Moreover, there is an important unobserved heterogeneity in patents data and patents are not a pure direct effect of inventions as they can also be used with a strategic purpose (Gittelman, 2008). In addition, this focus on patents led to a lack of heterogeneity in knowledge transfer research (Agrawal, 2001). Empirical research based on patents highlights a limited amount of knowledge transfer and royalties from patent licensing are usually very limited.

One assumes with several scholars that patenting offers a limited understanding of UIKT and that an alternative measure is required for a better capture of UIKT, more precisely to capture tacit knowledge transfer.

Informal mechanisms are "one[s] facilitating the flow of technological knowledge through informal communication processes" (Link et al., 2007, p. 642). Although "much of the knowledge developed through university research is tacit or can have different meanings depending on its interpretation by different actors" (Hayter et al., 2020, p. 3), few studies have investigated informal mechanisms of knowledge transfer. Examples of studies concern academics' propensity to engage in informal university technology transfer (see, e.g., Link et al., 2007) or the complementarities and interactivity of formal and informal mechanisms (see, e.g., Schaeffer et al., 2020; Azagra-Caro et al., 2017).

Various settings allow knowledge that is not patent-based to be transferred, such as conferences and academic consulting (Perkmann & Walsh, 2008). Conferences allow to enable contacts, social relationships and network between academic scientists and firms (Azagra-Caro et al., 2017; Perkmann & Walsh, 2008). Academic consulting allows to transfer the tacit and complex expertise needed to successfully exploit technologies licensed in a patent (Perkmann & Walsh, 2008). These settings highlight the importance of socialization to transfer tacit knowledge. This is why firms often arrange consulting contracts with Professors that published patents. By doing

so, they gain access to their tacit knowledge. The recent movement of academic spin-off also exemplifies mechanisms that allow tacit knowledge to be transferred with explicit knowledge (Pirnay et al., 2003).

4. Conceptual model: tacit knowledge transfer from academia to industry

4.1 The strength of ties: how embeddedness affects tacit knowledge transfer

Intensity of interactions between academic and industrial scientist depends on organizational settings. We distinguish inter-organizational interactions of individuals in two different organizations (i.e., university and enterprise) from professional mobility that brings individuals in the same organization.

Building on Granovetter (1973) concept of weak and strong ties and Nonaka (1994) concept of socialization, we propose that socialization of knowledge and interorganizational knowledge transfer occur in two forms: weak and strong socialization based on weak and strong ties. Nonaka assumes that socialization is important for the transfer of tacit knowledge (Nonaka, 1994). Granovetter (1973) explains that ties strength is a "combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie" (p. 1361). Therefore, one can draw the distinction between weak and strong ties as a function of the frequency and depth of actors' interactions. Socialization is the process by which actors share tacit knowledge through shared experience without the need of codification (Nonaka, 1994). This process allows actors to develop a common understanding.

1. Building the weak ties for tacit knowledge interorganizational transfer

Socialization between individuals that are part of two different organizations is weak socialization. Academic conferences or consulting projects allow sparse interactions between academic and industrial scientists (Cohen et al., 2002) and allows tacit UIKT to occur up to a certain level. Consulting projects often involve less cutting-edge scientific work (Boyer & Lewis, 1984; Perkmann & Walsh, 2007). Conferences allow social relationships formation (Perkmann & Walsh, 2007) but have limitations regarding the knowledge than can be transferred (Cohen et al., 2002). They are a setting to build weak ties. Although there are various benefits of weak ties, they might lead to issues for complex forms of knowledge (Hansen, 1999). Indeed, with weak socialization, common understanding and shared knowledge might occur at a low level only.

2. Building strong ties for interorganizational tacit knowledge transfer through academic scientists' mobility to industry

Strong socialization occurs when individuals are in the same organization and, therefore, interact frequently. Strong ties allow bidirectional interaction between agents, which enhances tacit knowledge assimilation, and moderate transfer problems (Hansen, 1999).

Organizations learn by recruiting (Simon, 1991). Recruiting academic scientists allows a firm to create a setting for frequent interactions between academic scientists and industrial scientists.

Labor mobility of science-skilled individuals has also demonstrated the same effect (Lacetera et al., 2004). Academic scholars' professional mobility has been studied, among others, regarding student preferences (Sauermann & Roach, 2012), career patterns (Stephan, 2006), and as a mean of transfer of embodied knowledge (Zellner, 2003). Research acknowledges its importance in university-industry links (see, e.g., Salter & Martin, 2001; Schartinger et al., 2002) and there are evidences that individual mobility has an important role in knowledge movement between organizations (Buenstorf & Heinisch, 2020). Hired scientists facilitate subsequent disembodied UIKT, bring problem-solving, extra-mural research evaluation,

external knowledge recognition and assimilation skills (Zellner, 2003), increase absorptive capacity (Cohen & Levinthal, 1990), and could prevent some barriers from appearing, such as strategic misalignment (Alexander et al., 2020). Labor mobility between university and industry is, e.g., an important channel of knowledge transfer when there is an expectation of breakthroughs and when the knowledge is not easy to codify and, consequently, to be published (Bekkers & Bodas Freitas, 2008). As knowledge is located in human heads, the mobility of PhD graduates to the industry thus represents one mechanism for the transmission of tacit knowledge (Stephan, 2006). Buenstorf and Heinisch (2020) defined PhD graduates as "highly specialized expert who worked for several years on advancing the state of the art in their field of research" (p. 1). They also highlighted that most of the knowledge they gained is tacit and that labor mobility provides a knowledge transfer channel from universities to the private sector (Buenstorf & Heinisch, 2020). Recruiting PhD graduates is an organizational device allowing strong socialization to occur between academic and industrial scientists. PhD graduates are mobile scientists (Mangematin & Robin, 2003) and are thus a privileged vehicle to the transfer of tacit knowledge between academia and industry. By recruiting, organizations create socialization by bridging academic and industrial scientists. Indeed, Buenstorf and Heinisch (2020) acknowledge that:

> "if hiring scientists and other experts allows firms to access their "embodied" knowledge including tacit components that are difficult to acquire otherwise, then one might expect the hiring of recently graduated PhDs to be an important strategy of knowledge sourcing and a direct channel of "embodied" knowledge transfer from universities to industry" (p. 3).

Scientific fields might also play a role regarding the level of mobility such as shown by Zolas et al. (2015). The transferability of academic knowledge varies as a function of the nature of academic specialization but also of the alignment between the academic specialization and the industrial specialization of the ecosystem.

Considering PhD graduates professional mobility of a pluridisciplinary university may give a broader and different understanding on knowledge transfer from academia to industry, especially from academic fields that do not patent knowledge.

Considering the influence of the nature of knowledge on its transfer mechanism (Bekkers & Bodas Freitas, 2008) and of the industrial application of the scientific domain on the mobility toward industry, we argue that the interorganizational mobility of academic scientists is a function of the scientific domain of those academic scientists and thus propose the following hypothesis:

H: As a function of both the knowledge characteristics and industrial application of their scientific domains, some departments tend to send a major proportion of their PhD graduates to industry and, conversely, other departments tend to send a major proportion of their PhD graduates to academia.

Conversely, industrial sectors might need various scientific skills and tacit knowledge. We thus propose the following hypothesis (H2):

H2: some industries have a more diversified recruitment of PhD graduates (pluri-faculties industries) than others and, conversely, other industries have a less diversified recruitment of PhD graduates than others (mono-faculties industries).

4.2 Transfer of tacit knowledge to local ecosystem

Science contribute to economic development (Etzkowitz & Leydesdorff, 2000) and UIKT is assumed to be a key determinant of regional development (Bramwell & Wolfe, 2008; Goldstein & Renault, 2004). Knowledge transfer from universities to local industrial clusters is thus a

factor of development. By contributing to their local industrial cluster, universities nourish an innovation and knowledge ecosystem. There are evidences of the importance of localization for knowledge spillovers (Alcácer & Chung 2007). Ferrary and Granovetter (2009) described Silicon Valley as a network of organizations that generates innovation and where the knowledge transfer from universities (Stanford, UC Berkeley, UC San Francisco, etc.) to regional large and small firms is an explanatory factor of the regional innovation capacity. In that sense, Trippl (2013) shows that academic scientists' mobility is a wide-spread phenomenon which results in UIKT within and between region depending on their mobility patterns. Moreover, he points out that academic scientists embed themselves in their destination regions through the creation of ties with regional actors (Trippl, 2013). Being able to keep academic scientists within their education region is thus important to enhance UIKT within this region. These elements arise the question of the transfer of tacit knowledge to the local ecosystem.

Various reasons might explain why individuals stay in or go out of the country in which they studied. Firstly, the mobility of PhD graduates might be explained by attractivity factors of the degree of the country in which they received their diploma: the more attractive the training country compared to the country of origin, the higher the probability that the PhD graduate will stay in the training country. Secondly, one might ask why national individuals tend to stay and foreign individuals tend to leave. In this sense, Cerase (1972) proposes a typology of return of migrants to their home countries and identify what he calls *return of conservatism*. It is the phenomenon of individuals that already planned to come back to their countries before migrating. One could thus argue that, for foreign citizens, doing a PhD in top-academic country is a mean to achieve specific career goals but not necessarily to settle there permanently. One could thus draw a typology of universities as a function of their capacity to attract and to retain foreign students: transit universities (which attract foreign students but do not retain them within the region) and installation universities (which attract foreign students and retain them within the region).

The elements above led us to the following hypotheses on geographical destination:

One could argue that the probability of staying in the local area where PhD graduates did their study is a function of the alignment between their scientific domain and the industrial specialization of this specific local area. We thus propose the following hypothesis (H3):

H3: Local industrial specialization: the more the academic specialization is aligned with the local industrial specialization, the more PhD graduates remain in the local area.

The citizenship of PhD graduates might also explain to a certain extent the installation in or the migration out of the local area, which lead to the following hypotheses (H4a and H4b):

H4a: local citizens tend to remain more in the local area for personal reasons (family, friends, culture, etc.) and, conversely, foreigners tend to migrate and return to their country.

H4b: local citizens tend to work in the local area for organizations with headquarters localized within the country and, conversely, foreigners tend to work outside of the local area for organization with foreign headquarters.

5. Methodology

5.1 Data

To address our research questions, we compiled a database composed of all PhD graduates of a large pluridisciplinary European university who defended their thesis in 2014 and 2015 (N=599). PhD graduates are a large population and can go either in academia or industry after their graduation. The Geneva region (geographical district) in which the university is localized encompass lot of activities related to banking, international organization and legal affairs. The first employer is the public sector[3]. Regarding the private sector, the region is specialized in Consulting and services (22.33% of jobs), Medical/Biotechnology/Chemistry/Pharmaceuticals (MBCP) (11.16% of jobs) and Finance (9.56% of jobs)[4].

The university from which we extracted the data is ranked 59th in the 2020 Shanghai ranking, totalize 110,582 publications on Web of Science, published 39 patents according to the European Patent Office and 59 patents according to the Swiss Federal Institute of Intellectual Property, and possess its own technology transfer office (TTO) since 1999. The number of patents above highlight that explicit knowledge measures (i.e., patents) show that there is few UIKT through explicit knowledge although the University created a lot of knowledge through publications.

Thesis-related information were extracted from the university database, and career data through LinkedIn. PhD graduates' career data were collected with a 5 years' timeframe. Temporal distinction to classify a post-PhD experience within a given year was fixed according to the publication date of the PhD thesis ($Year_i$ = Public defense date + 365i where $i \in [1,5]$). Among the all population (N=599), we found professional data for 377 of them. The numbers and proportion of PhD graduates for each department, both for the population (N=599) and the sample (N=377) are available in appendix 1. We tested the representativeness of the departments size in our sample compared to the departments size in the population using the two-proportion z-test with Yates continuity correction (see results in appendix 1). Proportions are statistically equivalent when $p > 0.05$[5]. Citizenship of PhD graduates were categorized in the following categories: Swiss, European Union (EU) and outside of EU. Localization of PhD graduates were classified in the following categories: Geneva (i.e., Geneva region), Switzerland (without Geneva), EU and outside of EU. As we did not have access to identity documents of individuals nor them directly, we took the oldest entry of their LinkedIn profile as a proxy of their citizenship. The rationale behind the use of the EU category for both citizenship and localization of PhD graduates is the following: barriers to mobility exist between countries outside of EU on one side and countries within EU and/or the European Economic Area (EEA) on the other side. Within EU and EEA, citizen can move freely. We focus on the 5th year after PhD graduation in order to propose in-depth descriptive statistics and consider potential gap due to post-doc period. Descriptive statistics and analysis were done through the software R.

5.2 Descriptive statistics

Our sample is composed of 55.44% of men and 44.56% of women. Table 1 shows the distribution of citizenships in our sample. Table 2 shows the number of PhD graduates by faculties and departments.

[3] OFS/OCS. (2020). Statistique structurelle des entreprises

[4] *Ibid*.

[5] Note that the approximates might be incorrect for proportion test with too low values. The statistics concerned by this case are highlighted in red in appendix 1.

Table 1: Citizenship

Citizenship	Number of individuals
Swiss	170
EU	126
Outside of EU	81
Total	377

Table 2: Number of PhD graduates by faculties and departments

Faculties	Number of PhD graduates by faculty	Departments	Number of PhD graduates by department
Economics and Management	32	Institute of Information Service Science	2
		Information Science Institute	5
		Geneva Finance Research Institute	3
		Institute of Economics and Econometrics	11
		Institute of Management	7
		Research Center for Statistics	4
Humanities	17	Department of Modern French Language and Literature	2
		Department of Philosophy	3
		Department of English Language and Literature	1
		Department of Modern French Language and Literature	0
		Department of Linguistics	2
		Department of Romance Languages and Literatures	1
		Department of Ancient Studies	2
		Department of East Asian Studies	2
		Department of Art History and Musicology	1
		Department of General History	2
		Department of German Language and Literature	1
		Department of Romance Languages and Literatures	0
		School of French Language and Civilization	0
Law	18	Center for Banking and Financial Law	1
		Department of Commercial Law	2
		Department of Labor and Social Security Law	0
		Department of Private International Law	3
		Department of Public International Law and International Organization	7
		Criminal Law Department	0
		Department of Public Law	3
		Department of Legal History and Legal and Political Doctrines	1
		Department of Civil Law	1
Medicine	49	Interfaculty Center for Gerontology and Vulnerability Studies	1
		Section of Basic Medicine	17
		Section of Clinical Medicine	27
		Section of Dental Medicine	4
Psychology and education sciences	36	Section of Psychology	18
		Interfaculty Centre for Affective Sciences	1
		Section of Educational Sciences	15
		Training and Learning Technologies	2
Sciences	187	Department of Computer Science	21
		Department of Astronomy	4
		Section of Earth and Environmental Sciences	17
		Institute of Environmental Sciences	2
		Physics Section	30
		Biology Section	42
		Chemistry and Biochemistry Section	33
		Mathematics Section	6
		Section of Pharmaceutical Sciences	32
Social Sciences	29	Institute of Demography and Socioeconomics	6
		Department of Geography and Environment	7
		Department of Political Science and International Relations	8
		Department of Sociology	6
		Institute of Economic History Paul Bairoch	2
		Institute of Gender Studies	0
Theology	2	Autonomous Faculty of Protestant Theology	2
Translation and interpretation	7	Department of Translation	4
		Department of Interpretation	1
		Department of Multilingual Computer Processing	2
Total	**377**		**377**

6. Results

6.1 Departments-sectors

6.1.1 Academic faculties transferring PhD graduates to industry (supply side)

Table 3 shows the number and percentage of PhD graduates working in academia and industry by faculty, ranked by the percentage of PhD graduates in industry. We see that out of 377 PhD graduates, 40.85% of them work in academia and 59.15% of them work in industry[6]. Some faculties transfer more PhD graduates to industry than others. Medicine, Law, Economics and Management as well as Sciences are the faculties that transfer the most PhD graduates to industry. Social sciences, Translation and interpretation as well as humanities are the ones that transfer the less PhD graduates to industry. These results are consistent with our hypothesis H1: some faculties indeed transfer more PhD graduates to industry than other. Moreover, the faculties with the higher rates of UIKT are the ones that have industrial applications.

Table 3: Number and percentage of PhD graduates in industry and academia by faculty

(in all localization)

Faculties	Number of PhD graduates	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia
Medicine	49	39	79.59%	10	20.41%
Law	18	13	72.22%	5	27.78%
Economics and Management	32	23	71.88%	9	28.13%
Sciences	187	120	64.17%	67	35.83%
Theology	2	1	50.00%	1	50.00%
Psychology and education sciences	36	15	41.67%	21	58.33%
Social sciences	29	9	31.03%	20	68.97%
Translation and interpretation	7	1	14.29%	6	85.71%
Humanities	17	2	11.76%	15	88.24%
Total	377	223	59.15%	154	40.85%

Table 4 shows the same data as table 3 but for PhD graduates working in the Geneva region only. Faculties with too low number of PhD graduates are grouped in the category “other faculties” and excluded from the ranking. As for table 3, we see that Law, Medicine, Economics and Management as well as Sciences are the faculties that transfer the most PhD graduates to industry, and that Social sciences, Humanities, as well as Translation and interpretation are the ones that transfer the less PhD graduates to industry.

Table 4: Number and percentage of PhD graduates in industry and academia by faculty

(Geneva only)

Faculties	Number of PhD graduates	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia
Law	8	8	100.00%	0	0.00%
Medicine	21	18	85.71%	3	14.29%
Economics and Management	12	9	75.00%	3	25.00%
Sciences	45	32	71.11%	13	28.89%
Psychology and education sciences	18	8	44.44%	10	55.56%
Social sciences	9	1	11.11%	8	88.89%
Humanities	9	0	0.00%	9	100.00%
Translation and interpretation	5	0	0.00%	5	100.00%
Total	127	76	59.84%	51	40.16%

[6] Using a two-proportion z-test with Yates continuity correction, the difference is significant at a level of $p<.05$.

Table 5 shows the same data as table 3 but for PhD graduates working in Switzerland (without Geneva) only. We see that Medicine, Economics and Management as well as Sciences are the faculties that transfer the most PhD graduates to industry. Social sciences as well as Psychology and education sciences are the ones that transfer the less PhD graduates to Industry. Faculties with less than 5 PhD graduates have been grouped in the category "Other faculties".

Table 5: Number and percentage of PhD graduates in industry and academia by faculty

(Switzerland only without Geneva)

Faculties	Number of PhD graduates	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia
Medicine	21	18	85.71%	3	14.29%
Economics and Management	7	6	85.71%	1	14.29%
Sciences	59	46	77.97%	13	22.03%
Social sciences	15	7	46.67%	8	53.33%
Psychology and education sciences	12	5	41.67%	7	58.33%
Other faculties	4	3	75.00%	1	25.00%
Total	118	85	72.03%	33	27.97%

Table 6 shows the same data as table 3 but for PhD graduates working in EU only. Sciences, Law as well as Economics and Management are the faculties that transfer the most PhD graduates to industry, when Medicine, Social sciences as well as Psychology and education sciences are the ones that transfer the less PhD graduates to industry.

Table 6: Number and percentage of PhD graduates in industry and academia by faculty

(EU only)

Faculties	Number of PhD graduates	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia
Sciences	34	22	64.71%	12	35.29%
Law	4	2	50.00%	2	50.00%
Economics and Management	5	2	40.00%	3	60.00%
Medicine	3	1	33.33%	2	66.67%
Social sciences	3	1	33.33%	2	66.67%
Psychology and education sciences	3	0	0.00%	3	100.00%
Other faculties	2	0	0.00%	2	100.00%
Total	54	28	51.85%	26	48.15%

Table 7 shows the same data as table 3 but for PhD graduates working outside of EU only. Economics and Management, Psychology and education sciences as well as Medicine are the faculties that transfer the most PhD graduates to industry, when Humanities is the one that transfer the less PhD graduates to industry.

Table 7: Number and percentage of PhD graduates in industry and academia by faculty (Outside of EU only)

Faculties	Number of PhD graduates	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia
Economics and Management	8	6	75.00%	2	25.00%
Psychology and education sciences	3	2	66.67%	1	33.33%
Medicine	4	2	50.00%	2	50.00%
Sciences	49	20	40.82%	29	59.18%
Law	5	2	40.00%	3	60.00%
Humanities	6	1	16.67%	5	83.33%
Other faculties	3	1	33.33%	2	66.67%
Total	78	34	43.59%	44	56.41%

Table 8 shows the number and percentage of PhD graduates in industry by localization for each faculty. We see that PhD graduates coming from Law (61.54%), Psychology and Education (53.33%) as well as Economics and Management (39.13%) faculties are primarily localized in Geneva. PhD graduates coming from Translation and Interpretation (100%), Sciences (38.33%), as well as Social sciences (77.78%) are primarily localized in Switzerland. PhD graduates in Medicine are equally dispersed among Geneva and Switzerland (both 46.15%). To a certain extent, these results are coherent with the industrial specialization of the Geneva region (hypothesis H3). PhD graduates coming from Theology (100%) faculty are primarily localized outside of EU. PhD graduates coming from Humanities are equally dispersed among Switzerland and extra-European countries (both 50%).

Table 8: Number and percentage of PhD graduates in industry by faculty for each localization

Localization / Faculties	All localizations	Geneva		Switzerland		EU		Outside of EU	
	Number of PhD graduates in Industry	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry	Number of PhD graduates in Industry	Percentage of PhD graduates in Industry
Law	13	8	61.54%	1	7.69%	2	15.38%	2	15.38%
Psychology and education sciences	15	8	53.33%	5	33.33%	0	0.00%	2	13.33%
Medicine	39	18	46.15%	18	46.15%	1	2.56%	2	5.13%
Economics and Management	23	9	39.13%	6	26.09%	2	8.70%	6	26.09%
Sciences	120	32	26.67%	46	38.33%	22	18.33%	20	16.67%
Social sciences	9	1	11.11%	7	77.78%	1	11.11%	0	0.00%
Theology	1	0	0.00%	0	0.00%	0	0.00%	1	100.00%
Translation and interpretation	1	0	0.00%	1	100.00%	0	0.00%	0	0.00%
Humanities	2	0	0.00%	1	50.00%	0	0.00%	1	50.00%
Total	223	76	34.08%	85	38.12%	28	12.56%	34	15.25%

Table 9 shows the number and percentage of PhD graduates in academia by localization for each faculty. We see that PhD graduates coming from Translation and interpretation (83.33%), Humanities (60%), as well as Psychology and Education (47.62%) faculties are primarily localized in Geneva. PhD graduates coming from Social sciences, Medicine, as well as Sciences are equally dispersed among Geneva and Switzerland (respectively 40%, 30% and 19.40%). These results are less coherent with the industrial specialization of the Geneva region (hypothesis H3). It thus seems that there is an alignment between science fields and the fact of remaining in the local area more for industry than for academia. PhD graduates coming from Theology (100%) are primarily localized in EU. PhD graduates coming from Sciences (43.28%) are primarily localized outside of EU.

Table 9: Number and percentage of PhD graduates in academia by faculty for each localization

Localization / Faculties	All localizations	Geneva		Switzerland		EU		Outside of EU	
	Number of PhD graduates in Academia	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia	Number of PhD graduates in Academia	Percentage of PhD graduates in Academia
Translation and interpretation	6	5	83.33%	0	0.00%	1	16.67%	0	0.00%
Humanities	15	9	60.00%	1	6.67%	0	0.00%	5	33.33%
Psychology and education sciences	21	10	47.62%	7	33.33%	3	14.29%	1	4.76%
Social sciences	20	8	40.00%	8	40.00%	2	10.00%	2	10.00%
Economics and Management	9	3	33.33%	1	11.11%	3	33.33%	2	22.22%
Medicine	10	3	30.00%	3	30.00%	2	20.00%	2	20.00%
Sciences	67	13	19.40%	13	19.40%	12	17.91%	29	43.28%
Law	5	0	0.00%	0	0.00%	2	40.00%	3	60.00%
Theology	1	0	0.00%	0	0.00%	1	100.00%	0	0.00%
Total	154	51	33.12%	33	21.43%	26	16.88%	44	28.57%

6.1.2 Industry recruiting PhD graduates from the University (demand side)

Table 10 shows the number, percentage and heterogeneity of PhD graduates by sectors considering all localizations.

We use the Herfindahl-Hirschman Index (HHI) to measure the PhD heterogeneity of the industrial sectors sector. The formula of HHI is the following: $H = \sum_{i=1}^{N} s_i^2$ where S_i is the number of PhD graduates of department *i* divided by the number of PhD graduates among all departments and *N* is the number of departments. The HHI takes values between 1/N and 1. It approaches 1/N when there is heterogeneity (low concentration and equally distributed number of PhD graduates among departments), and reaches 1 when there is no heterogeneity (when all the PhD graduates come from one department).

We see that some industries recruit more PhD than others. Regarding the percentage of PhD graduates by sector, Academia (40.85%), MBCP (26.53%) and the public (10.34%) sectors are the ones that recruit the most PhD graduates. Energy (0.80%), Food (0.53%), Luxury goods (0.53%) and transport (0.53%) are the sectors that recruit the less PhD graduates.

Concerning the number of departments from which the PhD graduates are coming, Academia (41), public (19), Consulting and services (18) as well as MBCP (12) sectors are the ones with the highest number of departments from which they are recruiting. Alternatively, Energy (2), Food (2), Luxury goods (2) and Transport (2) are the sectors with the lowest number of departments from which they are recruiting.

Academia is the sector with the higher level of heterogeneity (0.049), followed by the public sector (0.094) and MBCP (0.144). Energy (0.556), Food (0.5), Luxury goods (0.5) and Transport (0.5) are the sectors with the lowest heterogeneity.

Those consistent differences in terms of percentage, number of departments and heterogeneity of PhD graduates by sectors are aligned with our hypothesis H2, as public, MBCP as well as Management and consulting sectors represent 67.22% of the employment in the region. It might also indicate that some specific industry needs to build on various cutting-edge skills. For example, the public sector work on various problematics that concern the population and the MBCP sector need employees that have a deep knowledge in different fields.

Table 10: Number, percentage and heterogeneity of PhD graduates by sectors

(all localizations)

Sectors	Number of PhD graduates by sector	Percentage of PhD graduates by sector	Number of departments from which the PhD graduates are coming	PhD heterogeneity (HHI)
Academic	154	40.85%	41	0.049
MBCP	100	26.53%	12	0.144
Public	39	10.34%	19	0.094
IT	26	6.90%	11	0.198
Consulting and services	24	6.37%	18	0.063
Finance	16	4.24%	11	0.148
NPO	9	2.39%	9	0.140
Energy	3	0.80%	2	0.556
Food	2	0.53%	2	0.500
Luxury goods	2	0.53%	2	0.500
Transport	2	0.53%	2	0.500
Total	377	100.00%		

Table 11 shows the same data as table 10 considering Geneva region localization only. We see that Academia (40.16%), MBCP (22.83%), public (13.39%) and the Consulting and services (10.24%) sectors are the ones that recruit the most PhD graduates.

Concerning the number of departments from which the PhD graduates are coming, Academia (30), Consulting and services (13) as well as MBCP (9) sectors are the ones with the highest number of departments from which they are recruiting. Alternatively, Finance (3), Energy (2) and Luxury goods (2) are the sectors with the lowest number of departments from which they are recruiting.

Academia is the sector with the higher level of heterogeneity (0.047), followed by Consulting and services (0.089) and the public sector (0.197). Finance (0.556), Energy (1) and Luxury goods (1) are the sectors with the lowest heterogeneity.

Table 11: Number, percentage and heterogeneity of PhD graduates by sectors

(Geneva localization only)

Sectors	Number of PhD graduates by sector	Percentage of PhD graduates by sector	Number of departments from which the PhD graduates are coming	PhD heterogeneity (HHI)
Academic	51	40.16%	30	0.047
MBCP	29	22.83%	9	0.225
Public	17	13.39%	8	0.197
Consulting and services	13	10.24%	13	0.089
IT	8	6.30%	5	0.313
NPO	4	3.15%	5	0.250
Finance	3	2.36%	3	0.556
Energy	1	0.79%	2	1.000
Luxury goods	1	0.79%	2	1.000
Total	127	100.00%		

Table 12 shows the same data as table 10 considering Switzerland localization only. We see that MBCP (40.68%) and Academia (27.97%) and the public (11.86%) sectors are the ones that recruit the most PhD graduates.

Concerning the number of departments from which the PhD graduates are coming, Academia (17), MBCP (11) as well as the public (10) sectors are the ones with the highest number of departments from which they are recruiting. Alternatively, Energy (1), Food (1), Luxury goods (1) and Transport (1) are the sectors with the lowest number of departments from which they are recruiting.

Academia is the sector with the higher level of heterogeneity (0.074), followed by public (0.122) and IT (0.188) sectors. Energy (1), Food (1), Luxury goods (1) and Transport (1) are the sectors with the lowest heterogeneity.

Table 12: Number, percentage and heterogeneity of PhD graduates by sectors

(Switzerland localization only)

Sectors	Number of PhD graduates by sector	Percentage of PhD graduates by sector	Number of departments from which the PhD graduates are coming	PhD heterogeneity (HHI)
MBCP	48	40.68%	11	0.139
Academic	33	27.97%	17	0.074
Public	14	11.86%	10	0.122
IT	8	6.78%	6	0.188
Consulting and services	5	4.24%	5	0.200
Finance	4	3.39%	4	0.250
NPO	2	1.69%	2	0.500
Energy	1	0.85%	1	1.000
Food	1	0.85%	1	1.000
Luxury goods	1	0.85%	1	1.000
Transport	1	0.85%	1	1.000
Total	118	100.00%		

Table 13 shows the same data as table 10 considering EU localization only. We see that Academia (48.15%), MBCP (18.52%) and IT (11.11%) sectors are the ones that recruit the most PhD graduates.

Concerning the number of departments from which the PhD graduates are coming, Academia (16) is the one with the highest number of departments from which they are recruiting. Alternatively, Transport (1) is the sector with the lowest number of departments from which it is recruiting.

Academia is the sector with the higher level of heterogeneity (0.077). Transport (1) is the sector with the lowest heterogeneity.

Table 13: Number, percentage and heterogeneity of PhD graduates by sectors

(EU localization only)

Sectors	Number of PhD graduates by sector	Percentage of PhD graduates by sector	Number of departments from which the PhD graduates are coming	PhD heterogeneity (HHI)
Academic	26	48.15%	16	0.077
MBCP	10	18.52%	5	0.240
IT	6	11.11%	4	0.333
Consulting and services	4	7.41%	3	0.375
Finance	4	7.41%	4	0.250
Public	3	5.56%	3	0.333
Transport	1	1.85%	1	1.000
Total	54	100.00%		

Table 14 shows the same data as table 10 considering localizations outside of EU only. Luxury goods and Transport sectors recruited zero PhD graduates. We see that Academia (56.41%) and MBCP (16.67%) sectors are the ones that recruit the most PhD graduates.

Concerning the number of departments from which the PhD graduates are coming, Academia (22), is the sector with the highest number of departments from which they are recruiting. Alternatively, Energy (1) and Food (1) are the sectors with the lowest number of departments from which they are recruiting.

Academia is the sector with the higher level of heterogeneity (0.094). Energy (1) and Food (1) are the sectors with the lowest heterogeneity.

Table 14: Number, percentage and heterogeneity of PhD graduates by sectors

(Outside of EU localization only)

Sectors	Number of PhD graduates by sector	Percentage of PhD graduates by sector	Number of departments from which the PhD graduates are coming	PhD heterogeneity (HHI)
Academic	44	56.41%	22	0.094
MBCP	13	16.67%	6	0.278
Finance	5	6.41%	4	0.280
Public	5	6.41%	4	0.280
IT	4	5.13%	2	0.500
NPO	3	3.85%	3	0.333
Consulting and services	2	2.56%	2	0.500
Energy	1	1.28%	1	1.000
Food	1	1.28%	1	1.000
Total	78	100.00%		

Table 15 contains the department-sector matrix[7] from which the tables above are extracted. It contains the faculties and departments of the University on the vertical axis and the industrial sectors in which the PhD graduates are working on the horizontal axis. We used the industrial sectors indicated by LinkedIn and then refined it in order to have more meaningful categories.

The matrix shows interesting results. For example, the public sector has a really diverse recruitment of PhD graduates. They recruit from departments from all faculties apart from Humanities, Theology as well as Translation and Interpretation. The Consulting and services sector also has a diverse recruitment: they recruit PhD graduates from departments that are part of Economics and Management, Law, Psychology and education sciences, Sciences, as well as Social sciences faculties. These two examples document the need for industrial sectors to gain access to the tacit knowledge of academic scientists: by recruiting from diverse departments, they gain access to both idiosyncratic skills of specific science domains as well as more general cross-domains research skills.

The analysis of the matrix proposes an alternative view of UIKT. Various sectors that do not patent appear to recruit PhD graduates from a set of different academic departments. For example, the finance sector recruits PhD graduates from economics, philosophy, law, IT and political sciences. We show that PhD graduates' mobility is more diversified than depicted by patent-based mobility data and illustrate the possible transfer of both general research skills and domain-specific skills.

[7] The abbreviations meaning are the following: IT: Information technologies; MBCP: Medical, biotechnologies, chemistry and pharmaceuticals; NPOs: Nonprofit organizations; PhDoutA: Number of PhD graduates out of academia; PhDinA: number of PhD graduates in academia; PhDnb: Number of PhD graduates: PropOAD: proportion of PhD graduates outside of academia by department; PropOAF: Proportion of PhD graduates outside of academia by faculty.

Table 15: Department-sector matrix (all localizations)

Faculties	Departments	Academic	Consulting and services	Energy	Finance	Food	IT	Luxury goods	MBCP	NPO	Public	Transport	PhDoutA	PhDinA	PhDnb	PropOAD	PropOAF
		Sectors															
Economics and Management	Geneva Finance Research Institute	0	0	0	1	0	1	0	0	0	1	0	3	0	3	100.00%	71.88%
	Information Science Institute	2	0	0	1	0	1	0	0	1	0	0	3	2	5	60.00%	
	Institute of Economics and Econometrics	2	1	0	5	0	1	0	0	0	2	0	9	2	11	81.82%	
	Institute of Information Service Science	0	0	0	0	0	1	0	1	0	0	0	2	0	2	100.00%	
	Institute of Management	3	2	0	0	0	2	0	0	0	0	0	4	3	7	57.14%	
	Research Center for Statistics	2	0	0	0	0	0	0	0	0	2	0	2	2	4	50.00%	
Humanities	Department of East Asian Studies	2	0	0	0	0	0	0	0	0	0	0	0	2	2	0.00%	11.76%
	Department of Art History and Musicology	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0.00%	
	Department of General History	2	0	0	0	0	0	0	0	0	0	0	0	2	2	0.00%	
	Department of German Language and Literature	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0.00%	
	Department of English Language and Literature	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0.00%	
	Department of Modern French Language and Literature	2	0	0	0	0	0	0	0	0	0	0	0	2	2	0.00%	
	Department of Linguistics	2	0	0	0	0	0	0	0	0	0	0	0	2	2	0.00%	
	Department of Philosophy	2	0	0	1	0	0	0	0	0	0	0	1	2	3	33.33%	
	Department of Romance Languages and Literatures	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0.00%	
	Department of Antiquities	1	0	0	0	0	0	0	0	1	0	0	1	1	2	50.00%	
Law	Center for Banking and Financial Law	0	0	0	1	0	0	0	0	0	0	0	1	0	1	100.00%	72.22%
	Department of Legal History and Legal and Political Doctrines	0	1	0	0	0	0	0	0	0	0	0	1	0	1	100.00%	
	Department of Civil Law	0	1	0	0	0	0	0	0	0	0	0	1	0	1	100.00%	
	Department of Commercial Law	0	2	0	0	0	0	0	0	0	0	0	2	0	2	100.00%	
	Department of Private International Law	1	2	0	0	0	0	0	0	0	0	0	2	1	3	66.67%	
	Department of Public International Law and International Organization	3	1	0	1	0	0	0	0	1	1	0	4	3	7	57.14%	
	Department of Public Law	1	1	0	0	0	0	0	0	0	1	0	2	1	3	66.67%	
Medicine	Interfaculty Center for Gerontology and Vulnerability Studies	0	0	0	0	0	0	0	0	0	1	0	1	0	1	100.00%	79.59%
	Section of Clinical Medicine	3	0	0	0	0	0	0	17	0	7	0	24	3	27	88.89%	
	Section of Dental Medicine	1	0	0	0	0	0	0	3	0	0	0	3	1	4	75.00%	
	Section of Basic Medicine	6	0	0	1	0	0	0	10	0	0	0	11	6	17	64.71%	
Psychology and education sciences	Interfaculty Centre for Affective Sciences	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0.00%	41.67%
	Section of Psychology	6	1	0	0	0	2	0	4	0	5	0	12	6	18	66.67%	
	Section of Educational Sciences	12	1	0	0	0	0	0	0	1	1	0	3	12	15	20.00%	
	Training and Learning Technologies	2	0	0	0	0	0	0	0	0	0	0	0	2	2	0.00%	
Sciences	Department of Astronomy	4	0	0	0	0	0	0	0	0	0	0	0	4	4	0.00%	64.17%
	Department of Computer Science	4	2	1	1	0	10	0	2	1	0	0	17	4	21	80.95%	
	Institute of Environmental Sciences	0	1	0	0	0	0	0	0	0	1	0	2	0	2	100.00%	
	Biology Section	17	1	0	0	0	1	0	19	1	3	0	25	17	42	59.52%	
	Chemistry and Biochemistry Section	10	2	0	0	1	2	1	15	0	1	1	23	10	33	69.70%	
	Mathematics Section	2	0	0	2	0	1	0	1	0	0	0	4	2	6	66.67%	
	Physics Section	14	2	0	1	1	4	1	5	1	1	0	16	14	30	53.33%	
	Section of Earth and Environmental Sciences	11	1	2	0	0	0	0	3	0	0	0	6	11	17	35.29%	
	Section of Pharmaceutical Sciences	5	1	0	0	0	0	0	20	0	6	0	27	5	32	84.38%	
Social sciences	Department of Geography and Environment	4	0	0	0	0	0	0	0	1	2	0	3	4	7	42.86%	31.03%
	Department of Political Science and International Relations	5	1	0	1	0	0	0	0	0	1	0	3	5	8	37.50%	
	Department of Sociology	5	0	0	0	0	0	0	0	0	1	0	1	5	6	16.67%	
	Paul Bairoch Institute of Economic History	1	0	0	0	0	0	0	0	0	1	0	1	1	2	50.00%	
	Institute of Demography and Socioeconomics	5	0	0	0	0	0	0	0	0	1	0	1	5	6	16.67%	
Theology	Autonomous Faculty of Protestant Theology	1	0	0	0	0	0	0	0	1	0	0	1	1	2	50.00%	50.00%
Translation and interpretation	Department of Interpretation	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0.00%	14.29%
	Department of Translation	4	0	0	0	0	0	0	0	0	0	0	0	4	4	0.00%	
	Department of Multilingual Computer Processing	1	0	0	0	0	0	0	0	0	0	1	1	1	2	50.00%	
Total	**Number of PhD graduates by ector**	**154**	**24**	**3**	**16**	**2**	**26**	**2**	**100**	**9**	**39**	**2**					
	Number of departments by sector	**41**	**18**	**2**	**11**	**2**	**11**	**2**	**12**	**9**	**19**	**2**					
	Herfindal-Hirschman Index	**0.05**	**0.06**	**0.56**	**0.15**	**0.50**	**0.20**	**0.50**	**0.14**	**0.14**	**0.09**	**0.50**					

6.2 Citizenship-localization

Table 16 shows the citizenship-localization matrix of our sample. It contains the citizenship of the PhD graduates on the vertical axis and the localization of the organization in which they are working on the horizontal axis. Percentage are equal to the number of people of a citizenship category in a specific localization category divided by the total number of people of this same citizenship. We see that 33.69% of PhD graduates are localized in Geneva, followed by Switzerland (31.30%), extra-European countries (16.18%) and EU (14.32%). Looking at the localization of PhD graduates as a function of their citizenship, we see that Swiss PhD graduates are primarily localized in Geneva (43.45%), followed by Switzerland (39.41%), extra-European countries (12.35%) and EU (4.71%). For European individuals, the majority of them work in EU (30.16%), followed by Switzerland (29.37%), Geneva (27.78%) and extra-European countries (12.70%). People with an extra-European citizenship work primarily outside of EU (46.91%), followed by Geneva (22.22%), Switzerland (17.28%) and EU (9.88%). Using the Chi-squared test, we see that there is a relation between citizenship and organization localization (χ^2= 96.983, df = 6, p-value < 2.2e-16).

We thus see that the university is an attractor of foreign scholars (a large majority of the PhD graduates, 54.91%, are foreign students) both for Geneva and Switzerland.

Table 16: Citizenship-localization matrix

Localization / Citizenship	Organization localization				Total (Citizenship)
	Geneva	Switzerland	EU	Outside of EU	
Swiss	74 (43.45%)	67 (39.41%)	8 (4.71%)	21 (12.35%)	170 (100%)
EU	35 (27.78%)	37 (29.37%)	38 (30.16%)	16 (12.7%)	126 (100%)
Outside of EU	18 (22.22%)	14 (17.28%)	8 (9.88%)	41 (46.91%)	81 (100%)
Total (Localization)	127 (33.69%)	118 (31.30%)	54 (14.32%)	78 (16.18%)	377 (100%)

Table 17 shows the same data as table 16 but only for PhD graduates working outside of academia. We see that 38.12% of PhD graduates are localized in Switzerland, followed by Geneva (34.08%), extra-European countries (15.25%) and EU (12.56%). Looking at PhD graduates a function of their citizenship, we see that Swiss PhD graduates are primarily localized in Switzerland (47.06%), followed by Geneva (43.14%), extra-European countries (6.86%) and EU (2.94%). For European individuals, the majority of them work in Switzerland (35.14%), followed by EU (28.38%), Geneva (25.68%) and extra-European countries (10.81%). For extra-European individuals, the majority of them work in extra-European countries (40.43%), followed by Geneva (27.66%), Switzerland (23.40%) and European Union (8.51%). Using the Chi-squared test, we see that there is a relation between citizenship and organization localization (χ^2 = 57.616, df = 6, p-value = 1.371e-10).

Regarding Swiss citizens, the university train individuals that mainly stay in Switzerland. We observe a talent drain for extra-European citizen: 40.43% of them works for an organization outside of EU after their PhD in Geneva. These results are consistent with our hypothesis H4a.

Table 17: Citizenship-localization matrix (outside of academia)

Localization / Citizenship	Organization localization				Total (Citizenship)
	Geneva	Switzerland	EU	Outside of EU	
Swiss	44 (43.14%)	48 (47.06%)	3 (2.94%)	7 (6.86%)	102 (100%)
EU	19 (25.68%)	26 (35.14%)	21 (28.38%)	8 (10.81%)	74 (100%)
Outside of EU	13 (27.66%)	11 (23.40%)	4 (8.51%)	19 (40.43%)	47 (100%)
Total (Localization)	76 (34.08%)	85 (38.12%)	28 (12.56%)	34 (15.25%)	223 (100%)

6.3 PhD graduates' citizenship- Employer nationality and localization

Table 18 shows the citizenship-employer nationality and localization matrix of our sample for both individuals working in industry and academia. It contains the citizenship of the PhD graduates on the vertical axis and the localization of both the organization's headquarters and the actual office in which they are working on the horizontal axis. We see that 64.99% of PhD graduates are localized in Switzerland (including Geneva). Swiss and European PhD graduates are primarily working for Swiss organizations localized in Switzerland (respectively 48.24% and 26.19%), when extra-European PhD graduates are primarily working for foreign organization abroad (26.93%) and academia abroad (30.86%). PhD graduates do not nourish swiss organizations abroad or foreign organizations in Switzerland. Thus, they do not nourish the international expansion of Switzerland or other countries. If they work in Switzerland, it is mainly for swiss organizations. If they work abroad, it is mainly for foreign organization. In addition, we see that PhD graduates working in Switzerland (including Geneva) are mainly Swiss citizens, when PhD graduates working in foreign countries (within and out of EU) are mainly European and extra-European citizens. These results are consistent with our hypothesis H4b.

Table 18: Citizenship-employer nationality and localization matrix

Employer nationality and localization / Citizenship	Swiss localization			Foreign localization			Total (Nationality)
	Swiss organization in Switzerland	Foreign organization in Switzerland	Academic in Switzerland	Swiss organization abroad	Foreign organization abroad	Academic abroad	
Swiss	82 (48.24%)	10 (5.88%)	49 (28.82%)	3 (1.76%)	7 (4.12%)	19 (11.18%)	170 (100%)
EU	33 (26.19%)	12 (9.52%)	37 (21.43%)	1 (0.79%)	28 (22.22%)	25 (19.84%)	126 (100%)
Outside of EU	21 (25.93%)	4 (4.94%)	7 (8.64%)	0 (0%)	23 (29.63%)	25 (30.86%)	81 (100%)
Total (Localization)	136 (36.07%)	26 (6.90%)	83 (22.02%)	4 (1.06%)	58 (15.65%)	69 (18.30%)	377 (100%)
Total in and out of Academia (Localization)	245 (64.99%)			132 (35.01%)			

7. Discussion

Coming back to our research questions, our results show that universities transfer tacit knowledge to industry and that local universities transfer tacit knowledge to local industrial sectors. In addition, we depict a deeper picture of tacit UIKT through the indicators of professional and geographical mobility and show that the majority of PhD graduates move to industry. Focusing on all the faculties of a university instead of a specific faculty or industrial sectors allows us to explore differences among scientific and industrial fields.

Geographically, tacit knowledge transfer to local ecosystem and in foreign and domestic business. We see that local universities transfer tacit knowledge to industrial clusters, but more for national citizen than foreign ones.

The extent of the interorganizational mobility of PhD graduates that we observed highlights the building of a strong socialization setting between academia and industry through the mobility of PhD graduates. As individuals and organizational actors are embedded in social networks, looking at the interorganizational mobility of PhD graduates allows us to depict the building of interorganizational ties among academic and industrial actors.

Various factors seem to drive tacit knowledge transfer: the academic specialization (some domains have more industrial application of the knowledge they produce than other), the industry that is recruiting (some industries need more cutting-edge scientific discoveries and methods, as well as research skills, than others) and the citizenship of PhD graduates (economic factors of the country from where foreign PhD graduates came might explain its stays or leave of Switzerland).

By analyzing PhD graduates professional and geographical mobility one brings a different perspective on knowledge transfer from Academia to industry. By considering that tacit knowledge is embodied in PhD graduates, tracking their mobility highlights an under-analyzed pipes of knowledge transfer. We complement the literature by proposing a conceptual model of socialization bridging Granovetter (1973, 1985, 2005) and Nonaka (1994) as well as a new indicator of UIKT. We argue that our measure, by looking at mobility itself instead of proxies of mobility, resolves the mismatch between theory and empirical data in actual studies on mobility. Finally, our analytical focus on all scientific domains of a specific university allows to study UIKT at the broad university level. Our results might also suggest that, as geographical proximity determine professional mobility, organization could be incentivized to localize themselves close to university in order to capture their knowledge. Moreover, this study allows academic scientists to analyze careers perspectives outside of Academia as a function of their science domain.

7.1 Department-sector

The results we observe highlight the diverse nature of PhD graduates after their graduation as well as the multiple links existing between academia and industry. We observe the recruitment of PhD graduates from various sectors and those sectors recruit PhD graduates from various faculties and departments. This diversified nature of UIKT links in our results depict a situation where frontiers between academia and industry are porous and where industry is not only interested in explicit knowledge of academic scientists but also in both their idiosyncratic and general skills. We also observe an alignment between the results and the industrial specialization of the region. This depict UIKT as driven by alignment between academia and industry: the more alignment, the more UIKT.

7.2 Citizenship-organization localization

The Geneva region retains more Swiss PhD graduates than both European and extra-European PhD graduates. The observed percentages of Swiss localization compared to Geneva localization for non-Swiss individuals might indicate that Geneva is nourishing the Switzerland ecosystem better than the Geneva one. Considering Geneva and Switzerland percentages together, these different results show more significant knowledge spillovers dynamics for both Swiss and European individuals than for extra-European ones. We see that the university act as an installation university for both Swiss and European individuals but as a transit university for extra-European individuals. Two factors could explain this result for extra-European individuals. Firstly, they might use the Swiss academic ecosystem as a mean to progress academically but that they do not necessarily plan to stay in Switzerland after their studies. Secondly, the legislation of EU and EEA is strict toward mobility of individuals that do not come from a country which is part of the EU or the EEA.

7.3 Citizenship- organization nationality and localization

The university nourish Swiss organizations localized in Switzerland and foreign organization localized abroad. Consequently, PhD graduates do not seem to nourish the international expansion of both Swiss and foreign organization, but to nourish local and foreign innovation ecosystems.

8. Limits

The number of PhD graduates is not the same across faculties and departments. The constitution of a database with equally larger number of PhD graduates by faculty/department or the completion of the database with additional years of graduation might help to pursue further analysis.

Various inference methods should be used in order to be able to identify the precise causes of our results and to test our hypotheses more robustly.

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Appendix 1: Numbers and proportion of PhD graduates by department

Faculties	Departments	N Population	N Sample	% Population	% Sample	P-Value
Architecture	Institute of Architecture	1	0	0.17%	0.00%	1
Economics and Management	Institute of Information Service Science	2	2	0.33%	0.53%	1
	Information Science Institute	7	5	1.17%	1.33%	1
	Geneva Finance Research Institute	4	3	0.67%	0.80%	1
	Institute of Economics and Econometrics	12	11	2.00%	2.92%	0.4838
	Institute of Management	8	7	1.34%	1.86%	0.706
	Research Center for Statistics	4	4	0.67%	1.06%	0.7651
Humanities	Department of Modern French Language and Literature	3	2	0.50%	0.53%	1
	Department of Philosophy	6	3	1.00%	0.80%	1
	Department of English Language and Literature	2	1	0.33%	0.27%	1
	Department of Modern French Language and Literature	2	0	0.33%	0.00%	0.6319
	Department of Linguistics	4	2	0.67%	0.53%	1
	Department of Romance Languages and Literatures	2	1	0.33%	0.27%	1
	Department of Ancient Studies	5	2	0.83%	0.53%	0.8737
	Department of East Asian Studies	2	2	0.33%	0.53%	1
	Department of Art History and Musicology	4	1	0.67%	0.27%	0.6312
	Department of General History	7	2	1.17%	0.53%	0.5018
	Department of German Language and Literature	1	1	0.17%	0.27%	1
	Department of Romance Languages and Literatures	2	0	0.33%	0.00%	1
	School of French Language and Civilization	1	0	0.17%	0.00%	1
Law	Center for Banking and Financial Law	1	1	0.17%	0.27%	1
	Department of Commercial Law	4	2	0.67%	0.53%	1
	Department of Labor and Social Security Law	1	0	0.17%	0.00%	1
	Department of Private International Law	3	3	0.50%	0.80%	0.8781
	Department of Public International Law and International Organization	13	7	2.17%	1.86%	0.9167
	Criminal Law Department	1	0	0.17%	0.00%	1
	Department of Public Law	5	3	0.83%	0.80%	1
	Department of Legal History and Legal and Political Doctrines	2	1	0.33%	0.27%	1
	Department of Civil Law	1	1	0.17%	0.27%	1
Medicine	Interfaculty Center for Gerontology and Vulnerability Studies	1	1	0.17%	0.27%	1
	Section of Basic Medicine	24	17	4.01%	4.51%	0.828
	Section of Clinical Medicine	68	27	11.35%	7.16%	0.0414
	Section of Dental Medicine	17	4	2.84%	1.06%	0.1018
Psychology and education sciences	Section of Psychology	30	18	5.01%	4.77%	0.9901
	Interfaculty Centre for Affective Sciences	1	1	0.17%	0.27%	1
	Section of Educational Sciences	35	15	5.84%	3.98%	0.2555
	Training and Learning Technologies	2	2	0.33%	0.53%	1
Sciences	Department of Computer Science	23	21	3.84%	5.57%	0.2669
	Department of Astronomy	7	4	1.17%	1.06%	1
	Section of Earth and Environmental Sciences	22	17	3.67%	4.51%	0.6299
	Institute of Environmental Sciences	2	2	0.33%	0.53%	1
	Physics Section	44	30	7.35%	7.96%	0.82
	Biology Section	56	42	9.35%	11.14%	0.4252
	Chemistry and Biochemistry Section	42	33	7.01%	8.75%	0.3836
	Mathematics Section	12	6	2.00%	1.59%	0.8249
	Section of Pharmaceutical Sciences	40	32	6.68%	8.49%	0.3536
Social Sciences	Institute of Demography and Socioeconomics	8	6	1.34%	1.59%	0.9593
	Department of Geography and Environment	10	7	1.67%	1.86%	1
	Department of Political Science and International Relations	10	8	1.67%	2.12%	0.7892
	Department of Sociology	16	6	2.67%	1.59%	0.3762
	Institute of Economic History Paul Bairoch	5	2	0.83%	0.53%	0.8738
	Institute of Gender Studies	1	0	0.17%	0.00%	1
Theology	Autonomous Faculty of Protestant Theology	5	2	0.83%	0.53%	0.8738
Translation and interpretation	Department of Translation	4	4	0.67%	1.06%	0.7651
	Department of Interpretation	2	1	0.33%	0.27%	1
	Department of Multilingual Computer Processing	2	2	0.33%	0.53%	1
Total		**599**	**377**	**100.00%**	**100.00%**	